SWEET POTATO (*IPOMOEA BATATAS*) PRODUCTION AND RESEARCH IN PAPUA NEW GUINEA

R. Michael Bourke*

ABSTRACT

Sweet potato production and research work in Papua New Guinea is reviewed. The estimated annual production is worth over K200 million. It is the staple food in most of the highlands and parts of the lowlands. In the central highlands, it provides between 65% and 90% of people's energy intake. Aspects reviewed are the significance and distribution of the crop, the timing and effect of its introduction, the crop's ecological place and role in various cropping systems, cultivars grown, cultural techniques used, systems of harvest, crop yield, major pest and disease problems, and future prospects.

Some 180 agronomic field trials have been carried out. Research work reviewed includes cultivar, inorganic fertilizer, method of cultivation, plant density, effect of weeds and weedicide, time to maturity, method of harvesting, tuber protein content analyses, storage and other agronomic studies. Also reviewed are the possible manufacture of a dried sweet potato product, littleleaf disease studies and work on sweet potato as a stockfeed. The status of current research is mentioned. Available data on the importance of sweet potato in people's diets and agriculture, number of cultivars used by different groups and yields under subsistence conditions are presented.

INTRODUCTION

This review is intended primarily to bring together data on sweet potato production and research in Papua New Guinea from published and unpublished sources. The reference list becomes, in effect, a bibliography of sweet potato in the country. In such a wide ranging paper the review of research work is of necessity only a summary. An adequate review, for example, of all organic and inorganic fertilizer trials would constitute a paper in itself. This review does however draw the attention of researchers to previous work. The cropping systems in which sweet potato are grown are defined and mapped. This updates and expands on earlier work of Brookfield (1962) and Kimber (1972a).

* Formerly Principal Horticulturist, Highlands Agricultural Experiment Station, Aiyura, E.H.P., Papua New Guinea. Present address: Department of Human Geography, R.S.Pac.S., Australian National University, Canberra, Australia.

SWEET POTATO CULTIVATION

Significance and distribution

Sweet potato (*Ipomoea batatas* (L.) Lam.) is by far the most important food crop in Papua New Guinea. The only production estimates are now 20 years old. Walters (1963) estimated annual production to be 1,223,000 tonnes from an approximate area of 72,000 hectares. Given the expansion of crop area since then, present production is probably worth over K200 million per year, if tubers are valued at a conservative 15 toea per kilogramme. No other single crop, including the export crops, contributes as much to the national economy. As well as being a major subsistence crop, sweet potato is an important cash crop and is the main crop grown at institutions, such as schools.

The principal products for human consumption are the tubers which are baked in a fire, boiled or steamed in a stone oven. Small tubers are used raw as pig feed and large herds of pigs are maintained on sweet potato tubers, particularly in the highlands. The vines and leaves are occasionally eaten by people as a green vegetable, but their main use is as pig feed.

Areas where sweet potato is the staple food or a significant co-staple are shown in *Figure 1*. It is cultivated extensively in the highlands at elevations between 1200 m and 2700 m where it is generally the staple food.

Production is generally increasing in the lowlands (0-600 m) and intermediate altitude zone (600-1200 m), together with that of *Xanthosoma* and cassava, at the expense of the traditional staples, particularly *Colocasia* taro. This change is occurring because of the loss of fertile forest land which is necessary for taro cultivation; the ease of cultivation of sweet potato; pest and disease problems of taro; and the loss of traditional values associated with other staples. On Bougainville and New Ireland for example, sweet potato has displaced the traditional staple taro to a large degree.

Available information on the contribution of sweet potato to villagers' diets and the proportion it constitutes of all food planted is summarized in *Table 1*. The dependence of people in the central highlands on sweet potato is striking. Here it provides an estimated 53% to 94% of people's energy intake, 19% to 73% of their protein intake, 56% to over 90% of their total food intake (by weight) and occupies 57% to 91% of total garden land planted to food crops. Venkatachalam (1962), Oomen and Malcolm (1958), Lambert (1975) and Harvey and Heywood (1983) all conducted dietary surveys in Yobakogl village in the Sinasina area of Chimbu Province. The most recent survey (Harvey and Heywood 1983) however shows that the contribution of sweet potato to the people's diet has declined considerably and it has been displaced by rice, flour and other imported goods. This trend is likely to be occurring elsewhere in the highlands. On the highland fringes and in the lowlands, sweet potato is of lesser significance because of the presence of other staple foods.

Introduction to Papua New Guinea

It is generally accepted that sweet potato was introduced to Papua New Guinea some time in the past 400 years following European exploration in the New World. Yen (1974) has proposed that it came to Papua New Guinea from the West Indies via Africa, India and the East Indies (Indonesia). Various authors have estimated that sweet potato has been in the highlands for 200 to 300 years. Some examples are Upper Kaugel Valley, minimum of 170 years (Bowers 1968); Kainantu area, 200 to 300 years (Watson 1965); Wahgi Valley, 250 years (Golson 1981); Tari Basin, 250 years (B.J. Allen, pers. comm.).

The effect of the comparatively recent introduction of sweet potato into the highlands has been controversial. Watson (1965, 1977) has suggested that a subsistence revolution occurred following its introduction. It is hypothesized that this revolution included radical changes in gardening patterns, an increase in the importance of pigs, a human population explosion, a change in the relationship between the sexes amongst the highlanders, changes in social structure and an increase in warfare. Other workers have rejected this hypothesis. Brookfield and White (1968) suggest instead that the introduction of the sweet potato was not of major relevance to the development of agriculture in the highlands, although its introduction has had some effects, such as an expansion of cultivation into areas of higher altitude, the clearing of montane forest and the resultant more extensive planting of casuarina trees to provide wood in deforested areas.

Golson (1982) agrees with Watson that the introduced sweet potato was superior

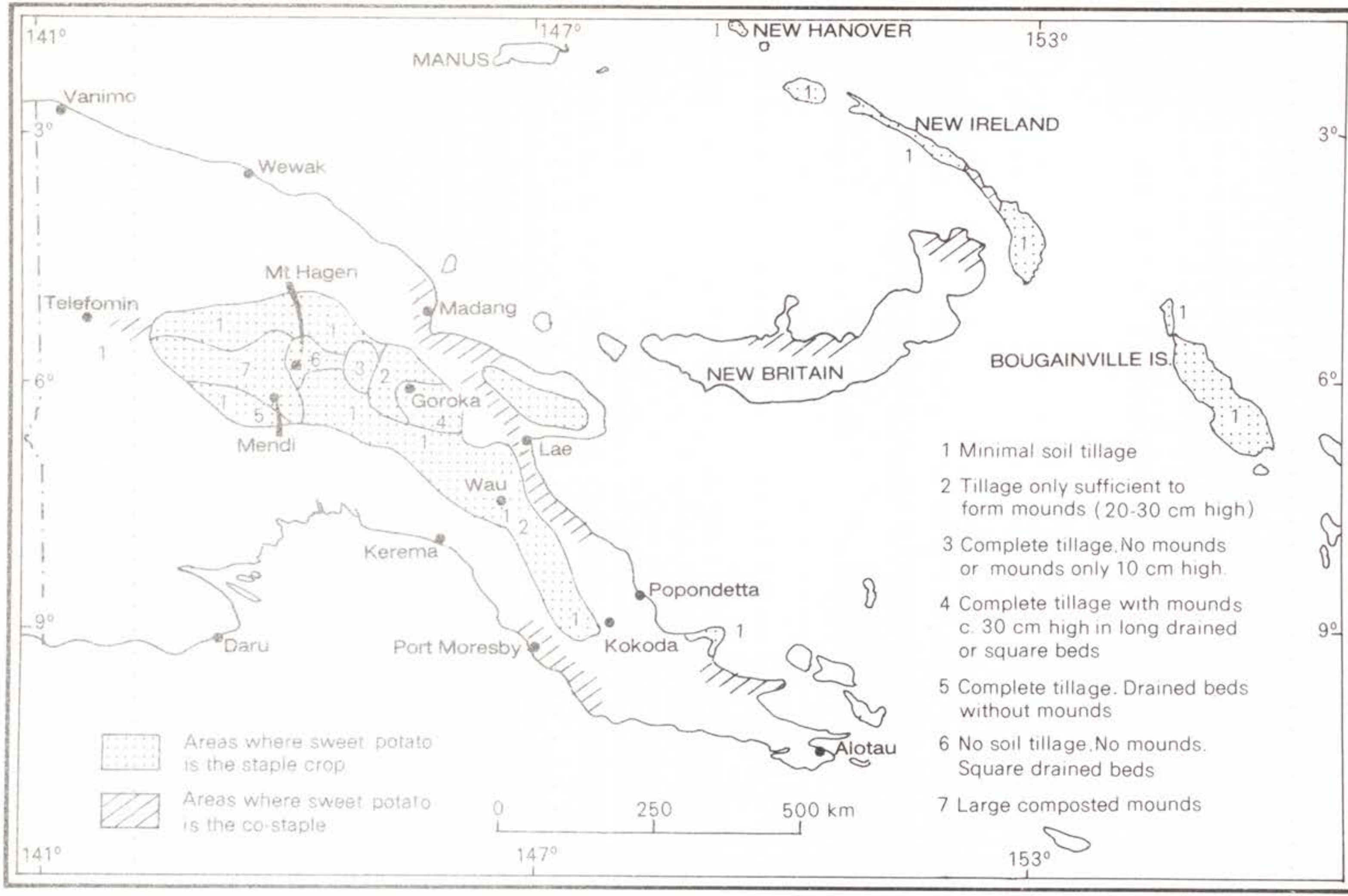

Figure 1. — **Sweet potato growing areas and tillage/plantings systems in Papua New Guinea**

Table 1.—**Importance of sweet potato in the diet of various groups of people in New Guinea**

Location *	Contributions of sweet potato (%)				Source
	Energy intake	Protein intake	Total food intake (by weight)	Area of food crops planted	
Gumine, Chimbu (2,3)	94	53	83	– (1)	Bailey & Whiteman (1963)
Sinasina, Chimbu (2)	92	–	89	–	Oomen & Malcolm (1958)
Baiyer R., W.H.P. (2)	89	73	86	–	Oomen & Corden (1970)
Kundiawa area, Chimbu (2,3)	87	48	80	–	Baily & Whiteman (1963)
Sinasina, Chimbu (2)	84	69	–	–	Lambert (1975)
Okapa, E.H.P. (2)	80	60	–	–	Jeffries (1978)
Okapa, E.H.P. (2)	78	41	–	–	Reid & Gajdusek (1969)
Upper Chimbu Valley (2)	77	41	70	–	Hipsley & Kirk (1965)
Sinasina, Chimbu (2)	76	56	77	–	Venkatachalam (1962) (4)
Lai Valley, Enga (2)	73	33	63	63-67	Waddell (1972)
Siane, Chimbu (3)	65	–	56	–	Salisbury (1962)
Lufa, E.H.P. (2)	64	37	–	–	Norgan *et al.* (1974)
Sinasina, Chimbu (2)	53	34	61	–	Harvey & Heywood (1983)
Nembi Plateau, S.H.P. (2,6)	47	19	–	–	Baines (1983)
Simbai, Madang Prov.	30	10-17	19	–	Rappaport (1968)
Simbai, Madang Prov.	25	–	16	–	Clarke (1971)
Upper Kaugel Valley, W.H.P. (2)	–	–	>90	–	Bowers (1968)
Sirunki Plateau, Enga (2)	–	–	90	–	Sinnett (1975)
Patep, South of Lae	–	–	38	–	Langley (1950)
Kaiapit, Markham V.	–	–	25	–	Langley (1950)
Trobriand Islands	–	–	14	–	Langley (1950)
Rigo, Central Prov.	4	2	4	–	Hipsley & Kirk (1965)
Middle Sepik E.S.P.	–	–	0.3	–	Oomen & Malcolm (1958)
Sirunki Plateau, Enga (2)	–	–	–	91	Allen (1982)
Wissel Lakes, Irian Jaya (2) (7)	–	–	–	>90	Pospisil (1963)
Nembi Plateau S.H.P. (2)	–	–	–	89	Bourke (in press)
Lai Valley, Enga (2)	–	–	–	87	Allen (1982)
Nagovisi, Bougainville	–	–	–	c.85-90	Mitchell (1976)
Tsak Valley, Enga (2)	–	–	–	83	Allen (1982)
Aiyura V., E.H.P. (2)	–	–	–	57(5)	R.M. Bourke (unpubl. data)

Notes: * Abbreviations used. E.H.P. — Eastern Highlands Province, E.S.P. — East Sepik Province, S.H.P. — Southern Highlands Province, W.H.P. — Western Highlands Province.

1 – = no data.

2 Locations in the central highlands of New Guinea.

3 Adult men only. Figures for other groups in the population are similar.

4 Venkatachalam's data were recalculated by Lambert (1975).

5 This figure is derived from measurements of crop area planted by 10 women over a 3 year period (1980-1982).

6 Pregnant women only.

7 Irian Jaya (West New Guinea) is a province of Indonesia.

to other pig feed, but also notes that it could be grown productively over a wider range of soils and altitudes. He maintains that agricultural production for pig keeping would have been less localized than prior to its introduction and thus it may have reduced inequality between men.

Ecological place and farming systems

Sweet potato is cultivated in a wide range of environments. It is grown from sea level to the altitudinal limit of agriculture in Papua New Guinea. This limit is in fact determined by where sweet potato will grow. It is usually at about 2700 m, but occurs as high as 2850 m in parts of Enga and Chimbu Provinces. The crop attains its greatest importance above 1200 m. Above 2300 m regular frost damage occurs.

It is the staple crop in areas where the mean annual rainfall ranges from 1500 mm (for example Mumeng) to about 5000 mm, (for example Pangia or Boku) and is grown on soil types ranging from sandy loams to heavy clays and peats. In the highlands where the crop is most important, the soils are generally loams or clays. It is grown on slopes ranging from flat land to 40°. The wide range of ecological conditions under which the crop is grown reflects both its adaptability and its wide genetic base within the country.

The farming systems in which sweet potato is grown are equally diverse. The crop is grown in systems using both grass and forest fallow. Grass fallow systems are more important, especially in the highlands. A number of cultivation systems can be distinguished and these are described below. Locations where the different systems are used are shown in *Figure 1*.

The cultivation techniques are as follows:

1. Minimal tillage. The soil is disturbed only enough to plant vines. This method is common in forest areas, especially in the lowlands, the fringes of the highlands and on forested land in the highlands as it is opened up for the first time.

2. Soil tilled sufficiently only to form mounds 20 to 30 cm high. The entire soil surface is not tilled. This method is practised in forested areas on slopes in the Eastern Highlands and parts of Chimbu Province. It is also used on light textured soils, such as sandy loams on river terraces, in both the lowlands and highlands (*Plate I*).

3. Complete soil tillage, but no mounds or mounds only 10 cm high. This is done in grassland areas on very steep slopes in the Chimbu Province. Horizontal soil retention fences made from branches are often used in this system.

4. Complete tillage with mounds about 30 cm high formed in long drained beds (Eastern Highlands) or in square beds (parts of Chimbu) and sometimes without beds (parts of Eastern Highlands). The entire soil surface is tilled prior to mounding. This system is mostly used in grassland soils but it is also practiced in forest soils. A peanut (*Arachis hypogaea* L.) or winged bean (*Psophocarpus tetragonolobus* (Linnaeus) A.P. de Candolle) rotation is commonly employed to maintain soil fertility.

5. Complete tillage with long drained, rectangular or square beds without mounds. This system is used in grassland soils in the Southern Highlands south of the composting zone (system 7).

6. No soil tillage. Deep drains 30 to 50 cm deep are dug to form beds 4 to 5 metres square. The spoil from the drains is thrown on top of the beds and sweet potato is planted into this loose soil. This system is used in the Wahgi, Baiyer and Nebilyer Valleys of the Western Highlands. A peanut and winged bean rotation is often used in this system.

7. Very large mounds 1.5 to 5 metres in diameter. Compost is formed within the mounds by placing grass and other organic material inside (Waddell 1972). This system is generally practised in grasslands in Enga, Southern Highlands and the western part of the Western Highlands Province. It is also used in forested areas on the fringe of the area where compost is used. D'Souza and Bourke (1982) give a more detailed map of where this system is practised (*Plates II and III*).

8. Mechanical soil tillage. Mounds or ridges are formed by hand or by tractor drawn implements. This system is practised by some commercial and institutional farmers on flat or gently sloping land in grassland areas in the lowlands and highlands.

The duration of the cropping and the fallow phases varies considerably in the cultivation systems described above. There is a tendency for intensity to increase from system 1 to 7 above. At one extreme a single crop of sweet potato is followed by a long forest fallow of up to 40 years duration. The other extreme occurs in the Tari Basin where sweet potato has been cultivated continuously for over 200 years with fallows of only 2-3 months between crops (Wood 1982).

Cultivars and cultural techniques

There are very many cultivars in Papua New Guinea. Yen (1974) suggests that more cultivars could be collected in Papua New Guinea than from any other area in the world. There are probably some 5000 cultivars grown. About 900 cultivars (including some duplicates) are maintained on research stations. Survey information on cultivars held by various groups of villagers is summarized in *Table 2*. The recorded number of cultivars held by any one group ranges from 6 to 71, with a mean of 33, although some of the lower figures are almost certainly underestimates. In the lowlands the number of cultivars held by any group of people is generally smaller than in the highlands (*Plate IV*).

The process which gives rise to new cultivars of a normally vegetative crop is spontaneous germination of true seeds, some of which produce cultivars which are retained and may eventually replace existing ones or may be grown along side existing ones. This process, cultural isolation of growers and growers' taste preferences explain the large numer of cultivars (Yen 1974; Powell *et al.* 1975). Cultivars introduced since European contact are rapidly replacing traditional ones and many traditional cultivars are now being lost (*Table 2*). Most cultivars are introduced from elsewhere in Papua New Guinea.

The crop is normally propagated by stem cuttings. These are almost always taken from the apical portion of the vine and cuttings from mature plants are preferred (Kimber 1972a). Surveys of crop densities have been conducted in five areas over a wide range of altitudes (*Table 3*). The range in crop density encountered within a limited area is very large. This is consistent with experimental work, described in a later section, which has shown that plant population does not have a major influence on crop yield. Vine and root pruning are both practised by some people. Cultivation of sweet potato in the highlands is mainly the responsibility of women. Men clear new areas, and do the heaviest work such as removing the basal parts of cane grass and fencing whilst the women prepare the soil and plant, weed and harvest the crop.

Systems of harvest and crop yield

The most common harvesting system is progressive removal of large tubers as they are needed. In the highlands, up to four harvests may be made from individual plants over a period of a year or more. On Bougainville (Mitchell, 1976) and in other lowland areas, a single harvest is taken and all tubers are

Plate I— **A sweet potato garden near Panguna, Bougainville. The crop is planted in small mounds following a secondary forest fallow (system 2)**

Plate II— Mounded sweet potato gardens (system 7) dominate the landscape in the Lai Valley near Wapenamanda in Enga

Plate III— **A woman and her daughters heap soil to form a composted mound near lake Kopiago in the far west of the composting zone. Grass used for the compost is in the right foreground**

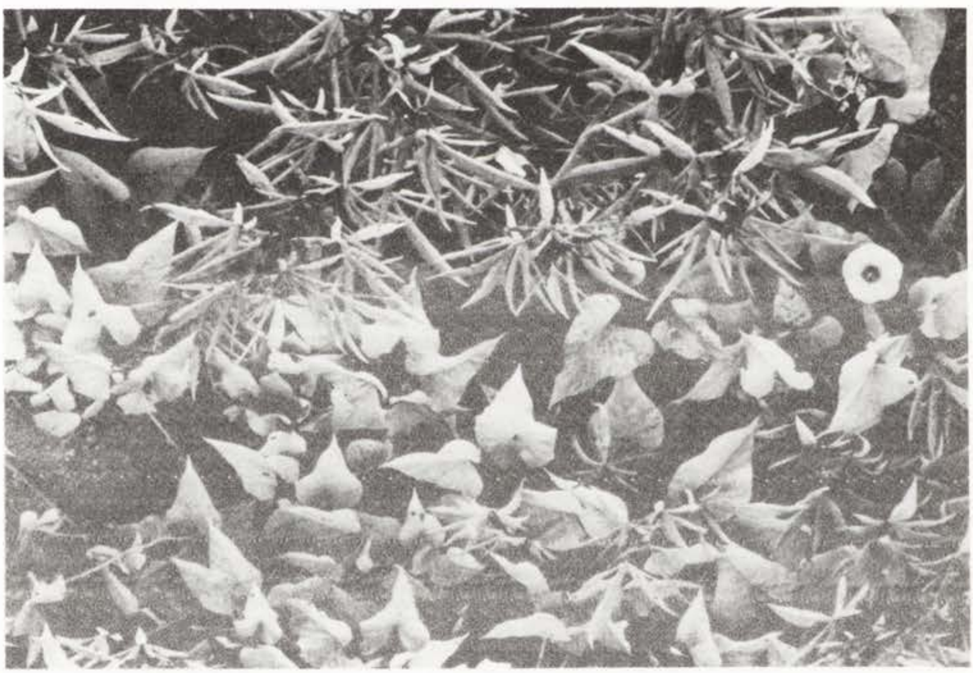

Plate IV— **A mixture of cultivars is used in a subsistence garden. It is estimated that there are of the order of 500 separate cultivars used in Papua New Guinea. Sweet potato growers maintain 33 cultivars on average**

Table 2. — **Number of sweet potato cultivars grown by various groups in New Guinea**

Location and approximate altitude(6)	Cultivars now grown			Traditional cultivars now lost	Source
	Total number	Traditional cultivars	Post-contact introductions		
Upper Chimbu Valley, Chimbu Prov.* (c.2200 m)	71	45	26	—(1)	Sterly (1978)
Baliem Valley, Irian Jaya* (1650 m) (2)	70 +	—	—	—	Heider (1970)
Sinasina area, Chimbu Prov.* (1800-2500 m)	67(3)	28	32	36	Hide *et al.* (1979)
Tari Basin* (1600 m)	53	—	—	—	Powell (1982)
Upper Mendi Valley, SHP* (2000 m)	49	30	19	—	Simpson (1978)
Simbai area, Madang Prov.* (1500-2300 m)	48(4)	43	5	—	Bulmer (1982)
Upper Mendi Valley, SHP* (2100 m)	42	—	Most cvs	22	Harrison (unpublished, 1976)
Mt. Hagen area, WHP* (1600-1900 m)	40-50	—	—	30-40	Powell *et al.* (1975)
Lai Valley, Enga* (1800 m)	35	—	—	—	Waddell (1972)
Upper Lai Valley, Enga* (2100 m)	31	25	6	—	Meggitt (1958)
Chimbu Province* (1500-2700 m)	30 +	—	—	—	Brookfield and Brown (1963)
Simbai area, Madang Prov.* (1500-2300 m)	29(5)	21	8	22	Bulmer (1982)
Upper Chimbu Valley, Chimbu Prov.* (1900 m)	29	—	—	—	Komba (1978)
Kainantu area, EHP* (1550-1800 m)	27	20	7	—	Watson (1967)
Nembi Plateau, S.H.P.* (1650 m)	25	11	14	25	Bourke (in press)
Obura area, EHP (1600-2300 m)	25	—	—	—	Hays (1981)
Simbai River, Madang Prov. (1300-1600 m)	24	—	—	—	Rappaport (1968)
Sirunki Plateau, Enga* (1900-2700 m)	24	—	—	—	Sinnett (1975)
Kagua area, SHP* (1600 m)	17	11	6	—	Abaya (1978)
Lamari River, EHP (1000-1700 m)	16	—	—	—	Boyd (1975)
Simbai River area, Madang Prov. (700-1100 m)	15 +	—	—	—	Clarke (1971)
Sirunki Plateau, Enga* (2600 m)	13	11	2	—	Walker (1966)
Pangia area, SHP* (1500-1600 m)	10	—	—	16	Paia (n.d.)
Markham Valley (300 m)	7	—	—	—	Langley (1950)
Snake River, Morobe Prov.* (1100 m)	6	—	—	—	Langley (1950)

Notes: * Sweet potato is the main staple food.
1. — = no data.
2. Irian Jaya (West New Guinea) is a province of Indonesia.
3. Includes 7 cultivars of unknown origin.
4. Situation in 1963-64.
5. Situation in 1980.
6. Abbreviations used: see *Table 1*, footnote.

Table 3. — **Crop densities of sweet potato observed in village gardens**

Location	Approximate altitude (m)	Sample size	Mean density (plants/ha)	Range of densities (plants/ha)	Source
Sirunki-Laiagam area, Enga Prov.	2350-2600	62	43,000	18,000-86,000	C. Tumana (pers. comm.)
Kerowagi-Kundiawa area, Chimbu Prov.	1650-1750	32	46,000	30,000-91,000	C. Tumana (pers. comm.)
Gazelle Peninsula, East New Britain	0- 400	30	49,000	15,000-172,000	R.M. Bourke (unpubl. data)
Kainantu area, E. Highlands Prov.	1550-1900	30	62,000	42,000-95,000	C. Tumana (pers. comm.)
Nembi Plateau, S. Highlands Prov.	1650-1700	27	76,000	38,000-110,000	E. D'Souza (pers. comm.)

removed at the same time, regardless of size. Tubers are occasionally stored in holes in the ground filled with sand (Kimber 1972a) and are also stored in dwellings for a few days before consumption (Siki 1979).

The available information on subsistence yields is summarized in *Table 4.* (Some figures in the literature are excluded as they are estimates only.) Reported subsistence yields range from 2 to 50 t/ha, with most values in the range 5 to 25 t/ha. Experimental yields have ranged from crop failure to 71.2 t/ha (Enyi 1977) with most between 10 and 40 t/ha. In the lowlands experimental yields of 10-20 t/ha are the rule, whilst in the highlands yields are often in the range 20-40 t/ha. Time to maturity is 5-6 months in the lowlands, 6-8 months in the highlands and 7-12 months (and longer) at high altitudes.

Pest and disease problems

Rats cause much damage to tubers. To reduce damage by rats, villagers often turn the vines to expose the soil to the sun and thus make the soil harder. Also women and children hunt and eat the rats.

Domestic and wild pigs can do much damage at times so that in most parts of Papua New Guinea individual gardens or groups of gardens are fenced in to keep pigs out.

The sweet potato weevil (*Cylas formicarius* (Fabricius)) can be a major problem, but is serious only in areas with a marked dry season, such as around Port Moresby, or in very dry years. The recommended control measure is crop rotation and use of uninfested planting material (Kimber 1972b; Smee 1965; Sutherland 1982a).

Hawkmoth (*Agrius convolvuli* (Linnaeus)) has been recorded as attacking sweet potato leaves, mainly in the lowlands. The damage is generally not severe, but it can defoliate a crop (Froggatt 1936, 1939). This pest is controlled by the introduced cane toad (*Bufo marinus* (Linnaeus)) (Anon. 1941).

The sweet potato leafminer (*Bedellia somnulentella* (Zeller)) has reduced yields in the highlands in some years (Kimber 1972b) and also in the Markham Valley (E.S.C. Smith, pers. comm.).

Other occasional insect pests are the vine borer (*Omphisia anastomosalis* Guenée), the large tortoise beetle (*Aspidomorpha* spp.), the small tortoise beetle (*Cassida* spp.), the horned weevil (*Apirocalus ebrius* Faust), black flea beetle (*Arsipoda tenimberensis* Jacoby), the sweet potato mirid (*Halticus tibialis* Reuter), and a sweet potato plant hopper (Sutherland 1982b).

Sweet potato littleleaf is a condition caused by a mycoplasma-like organism

Table 4. —**Sweet potato yields recorded in subsistence gardens in New Guinea**

Location and approximate altitude*	Yield (t/ha)	Source	Notes
Snake River area, Morobe Prov. (1100 m)	37.7-50.3	Conroy and Bridgland (1950)	
Tsak Valley, Enga Prov. (1500-1900 m)	33.2-37.0	Anon. (1967b)	Average over all soil types and slope classes
Tsak Valley, Enga Prov. (1900-2300 m)	31.3-34.9	Anon. (1967b)	Average over all soil types and slope classes
Oksapmin area, W. Sepik Prov. (1800 m)	31.1	Cape (1981)	
Tsak Valley, Enga Prov. (>2300 m)	27.6-30.7	Anon. (1967b)	Average over all soil types and slope classes
Chimbu Prov. (1900-2300 m)	24.0-26.6	Anon. (1967a)	Average over all soil types and slope classes
Kaugel Valley, WHP (2200 m)	23.5	Bowers (1968)	River terraces
Chimbu Prov. (< 1900 m)	22.5-24.9	Anon. (1967a)	Average over all soil types and slope classes
Enga Prov. (1500-1900 m)	22.4-25.0	Anon. (1967b)	Average over all soil types and slope classes
Lai Valley, Enga Prov. (1800 m)	20.9	Waddell (1972)	Small mounds
Enga Prov. (1900-2300 m)	21.2-23.6	Anon. (1967b)	Average over all soil types and slope classes
Enga Prov. (>2300 m)	18.6-20.7	Anon. (1967b)	Average over all soil types and slope classes
Mt. Hagen (1600 m)	18.4	Clarke (1977)	Good soil. After 8 year fallow
Lai Valley, Enga Prov. (1800 m)	17.4	Waddell (1972)	Large mounds
Upper Lai Valley, Enga Prov. (2100 m)	15.7	Meggitt (1958)	First crop on best soil
Chimbu Prov. (>2300 m)	15.0-16.6	Anon. (1967a)	Average over all soil types and slope classes
Upper Wage Valley, Enga Prov. (2650 m)	c.14.0	Wohlt (1978)	Per year
Kamu Valley, Irian Jaya (c.1500 m)	16.9	Pospisil (1963)	Complex cultivation
Kamu Valley, Irian Jaya (c.1500 m)	13.8	Pospisil (1963)	Shifting cultivation
Kopiago-Kelabo, S.H.P. (1400-1700 m)	13.6	Modjeska (1977)	
Tari Basin, SHP Prov. (1600 m)	13.1-13.3	Wood (1982)	Peaty soils
S.W. Bougainville Island (100 m)	12.2/8.5	Mitchell (1976)	First and fifth crops respectively. 21-22 weeks
Tari Basin, SHP (1600 m)	11.2-11.3	Wood (1982)	Alluvial soils
Mount Hagen (1600 m)	9.3	Clarke (1977)	Poor soil. In cultivation for 10-15 years
Nembi Plateau S.H.P. (1400-1700 m)	7.1	Crittenden (1982)	
Simbai River, Madang Prov. (1300-1600 m)	6.5	Rappaport (1968)	Over 120 weeks in mixed garden. Total garden production 15.5 t/ha
Nembi Plateau, SHP (1650 m)	6.3	Bourke (in press)	Soil fertility reduced by many years of cropping
Tari area, SHP (1600-1800 m)	5.4-8.5	Wood (1982)	Volcanic ash soils
Manus Island (100 m)	c.2.0	Rooney (1982)	Following taro blight epidemic, people changed briefly to a sweet potato staple

Note: * See *Table 1*, footnote for abbreviations.

(Pearson 1981, 1982) and transmitted by *Halticus tibialis* and by vegetative propagation (Van Velsen 1967). It is a serious problem in village gardens in Central Province and has also caused severe yield loss in experimental plots at Keravat in the past, although the condition is no longer present there.

Leafscab, caused by the fungus *Elsinoe batatas* Jenkins and Viegas, is common on sweet potato vines and leaves. This condition is worse in the highlands than in the lowlands and cultivars vary widely in resistance to it. Goodbody (1982) reported that scab caused a 50% yield loss in a fungicide trial in the highlands.

Leafspot (*Cercospora timorensis* Cooke) has been recorded many times from sweet potato in Papua New Guinea (Shaw 1963), but the economic significance is unknown.

In the Upper Mendi area of the Southern Highlands, sweet potato yields were severely reduced in 1980 by a condition associated with nematode damage and the fungus *Fusarium oxysporum* Schlechtenbal ex Fries (M. Anders, pers. comm.).

Constraints and future prospects

The constraints on crop production vary with the location and the type of farmer. In Central Province, littleleaf disease and sweet potato weevil can be major problems. Weevil can be a constraint in other dryer areas or in dry years. Inadequate soil moisture restricts planting in the dryer months in parts of the Eastern Highlands, Central Province and the Markham Valley, giving rise to some seasonality of production. Excessive soil moisture can also be a serious problem, especially on heavier soils in the highlands and in wetter years, leading to reduced crop yield or even crop failure.

Commercial production is mainly constrained by non-agricultural factors. Access to tractors in working order and for a reasonable price is a major constraint for some commercial farmers, especially in the Eastern Highlands. Transportation of produce and marketing problems are other major constraints.

Continuing expansion of production is likely in both the subsistence and commercial sectors. Courses for farmers in commercial sweet potato production have been run at Aiyura in the highlands and at Laloki near Port Moresby to encourage commercial production (Bourke 1982b; King 1982). Use of irrigation in the dry Port Moresby area has the potential to facilitate expansion of production to meet the high demand there. It is likely that sweet potato will continue to replace the traditional staples in the lowlands and intermediate altitude areas, as has already happened in some areas in recent decades.

RESEARCH WORK

Research on sweet potato in PNG has concentrated on crop agronomy, farming systems, use of the tubers for stockfeed, the littleleaf condition and production of a dried sweet potato product. Up to the end of 1982, some 180 agronomic field trials have been undertaken, mostly by staff of the Department of Primary Industry. A listing of 136 agronomic trials done on the crop between 1928 and 1978 is given by Bourke (1982a). The research work is briefly reviewed below.

Agronomic trials

Cultivar trials. Over 50 cultivar trials have been conducted at 11 locations. In these, yield, taste, resistance to leafscab and weevil, and protein content have been evaluated. Cultivars have been released mainly on the basis of high and stable yields and acceptable taste. Current releases are listed in *Table 5*. Introductions from Peru, the United States of America (USA) and the International Institute of Tropical Agriculture (IITA) in

Table 5.—**Recommended D.P.I. cultivars for various environments in Papua New Guinea (after Akus 1982, King 1982, Kurika 1982)**

Highlands	Dry Papuan lowlands	Humid lowlands
Markham 1	Keravat 40	K 9
Merikan	Doura 1	K13
Naveto	Laloki 2	
Serenta	Unu 1	
	NG 7571	

Nigeria have been evaluated. Peruvian cultivars imported from New Zealand in an attempt to obtain frost resistant material performed poorly and were not frost resistant. Cultivars from the USA have not yielded particularly well and the soft orange coloured tuber is not acceptable to Papua New Guineans' taste. Some of the IITA cultivars have yielded more than local material at Aiyura (1600 m), Laloki (80 m), and Tambul 2300 m) (Akus submitted for publication; King 1982). Evaluation of these cultivars is continuing.

Fertilizer trials. Over 50 trials on inorganic and organic fertilizer have been carried out, most of them in the highlands. Much of the highlands work on inorganic fertilizers is unpublished and results have not been very consistent. In some of the unpublished highland trials, increased yield responses to nitrogen, phosphate or potassium were recorded. In other trials, yields were depressed by fertilizer. Inconsistent responses may reflect different soil types or the effects of using different cultivars.

Results of published fertilizer trials in the highlands follow. In a trial in the Bismarck Mountains, Clarke and Street (1967) observed an increased yield response to a combined N, P and K fertilizer. In a trial at Aiyura that included various levels of a NPK mix and urea, treatment effects were somewhat inconsistent and barely significant. NPK appeared to be beneficial while urea had a nil or negative effect (Anon. 1972 p. 68). In another series of four trials at Aiyura, treatments were a NPK mix (sometimes in combination with Mg or a minor mix), sulphur, lime and control. In no case did fertilizer plots yield significantly better than unfertilized and any effect of fertilizer appeared to be a yield depression (Anon. 1972 pp. 69-70). In two trials at Aiyura and one near Goroka, Kimber (1982a) found increased yield responses to nitrogen and potassium but not to phosphate.

In a trial on the Nembi Plateau in the Southern Highlands, D'Souza and Bourke (in preparation) examined the effect of N,P,K,B and a minor mix. Potash gave a large increase in yield, whilst phosphate gave a small but significant increase and boron depressed yields.

Seventeen field and six pot trials have been undertaken on a young volcanic soil on New Britain in the lowlands (Bourke 1977b, 1978a). In most of these trials, nitrogen gave large yield increases, especially in grassland sites. Potassium increased yield in a depleted forest soil but not at other sites. In most trials, nitrogen increased tuber yield, but in others it depressed yield. The inconsistency in response to nitrogen was possibly because of the use of different cultivars.

Thirteen experiments on organic fertilizers have been performed in the highlands and lowlands. Organic fertilizers tested were: pig manure, chicken manure, coffee pulp, compost placed in the mound and azolla (*Azolla pinnata* R. Brown) (D'Souza and Bourke 1982, 1983, in preparation; Kimber 1982c; Leng 1982; Siki 1980; Thiagalingam and Bourke 1982; Velayutham *et al*. 1982; A.W. Wood, pers. comm.). In 12 of the 13 trials (the exception being one using chicken manure) organic fertilizer increased tuber yield. In one trial where no response was recorded, yield levels were already very high (Velayutham *et al* 1982). The consistent yield responses to organic fertilizers and the inconsistent responses to inorganic fertilizers suggest that yield responses are more likely with organic fertilizer than with inorganic fertilizer.

Method of cultivation. Seven experiments have compared plantings in ridges, mounds or flat land. In a trial on a sandy loam at Keravat (20 m) on New Britain, large hills and ridges gave a yield of 37.7 t/ha compared with 11.3 t/ha using the local method of small ridges (Anon. 1941). At Aiyura (1600 m) Kimber (1970, 1971, 1976a) compared flatland plantings with mounds and ridges of various sizes in 5 trials on mostly heavy soils. Flatland planting was very much inferior in most trials and mounds gave higher yields than ridges for corresponding size. On the other hand, C.J. Rose (pers. comm.) found no significant yield difference between large and small mounds and ridges on a light soil at Piwa (1600 m) in the Tari Basin.

Plant density. In seven trials at Aiyura plant densities ranging from 11,000 plants to 110,000 plants/ha were compared. There was very little difference in yield of marketable tubers (over 100 g weight) between treatments, but the yield of stockfeed tubers (under 100 g) increased with increasing density (A.J. Kimber, pers. comm.).

Effect of weeds and herbicide. Four herbicide trials and one trial examining the effect of weeds on yield have been carried out at Aiyura (Anon. 1973). It was found that yield was increased as the weed-free period after planting extends from 0 to 8 weeks. Paraquat ("Gramoxone" I.C.I.) at 0.14 litres a.i./500 litres water/ha applied at two and four weeks after planting gave good weed control.

Time to maturity. At Keravat in the lowlands, Jamieson (1968) examined various crop characteristics on one soil type with varied pre-crop histories using successive row by row harvesting of plots. He found that maxima in crop yield, number of tubers and flowers occurred earlier in more depleted soil; and that maximum flowering was a useful indicator of time of achievement of maximum yield.

Method of harvesting. Three comparisons have been made of single harvesting of all tubers versus progressive harvesting of large tubers. The latter technique is the universal practice in the highlands. Anon (1965) reported on a trial at Aiyura conducted for three and a half years. The single harvest technique gave higher yields than progressive harvesting. A.J. Kimber (pers. comm.) compared the two techniques for two cultivars over three plantings at Aiyura. He found that the average daily yield was greater with the single harvest method for the first planting. Kimber did not consider results from the second and third planting because yields were very much reduced. If they are considered however, the cumulative and daily yields from the two techniques are similar.

The third trial was done by Rose (1979) at Tari. A single planting was used with different growing periods for the two techniques. Rose reported that progressive harvest gave a greater total yield. However average daily yields (bulking rate) were not significantly different for the two techniques. The two techniques gave a different tuber size distribution, with the progressive harvesting giving a lower bulking rate for marketable tubers (over 100 g) and a higher bulking rate for smaller tubers (under 100 g).

The results of these three experiments could be interpreted in different ways. The present author's interpretation would be that the two techniques give similar bulking rates of total tuber yield, that is, if both were practiced over a long time period, the total yield achieved would be similar.

Tuber protein content. Because of the importance of sweet potato in highlanders' diets, tuber protein content can have a major effect on protein intake. The protein content of tubers from 11 Department of Primary Industry cultivar trials has been analysed. In addition, six reports of tuber protein content have been reviewed by Heywood and Nakikus (1982). Both published and unpublished analyses indicate that tuber protein content varies markedly between cultivars. For example, the range was 0.6-2.9% protein (fresh weight basis) in the series of analyses reviewed by Heywood and Nakikus (1982). Where the same cultivars have been analysed from different experiments, the ranking of the various cultivars was not very consistent from analysis to analysis. It is not clear whether this is because of variation in tuber protein content between plantings or because of problems in the techniques used. In one series of experiments, the protein content of three cultivars was increased by N or NPK fertilizer (Kimber 1976b).

Storage trials. Trials using various techniques of storing tubers have been carried out at Kandep (2350 m) and Kuk (1600 m) by Aldous (1976) and at Keravat (20 m) by Bourke (unpublished data). Aldous covered piles of tubers with dry grass to form mounds. Bourke covered tubers with dry grass and then a layer of soil to form clamps. It was found that it was possible to store tubers successfully for up to 50 days at Kandep, 40 days at Kuk and 30 days at Keravat. It is likely that the difference in storage times at the three locations is related to differences in air temperature.

Other agronomic studies. Sweet potato has been the main indicator crop used in various DPI farming systems trials. These include trials on soil exhaustion, crop rotation, intercropping and type of fallow (Bourke 1977a; D'Souza, Bourke and Akus, submitted for publication; Kesavan 1982; Kimber 1974; Kimber 1982b; Newton and Jamieson 1968). Growth analysis studies have been done by Bourke (1978b, 1984) and Enyi (1977). Uniformity studies have resulted in a recommended plot size of 16 m by 2.5 m for trial work (A.J. Kimber, pers. comm.), although in practice smaller plots are usually used. Mechanical cultivation of sweet potato has been evaluated in the Western Highlands by Fooks and Groedl (1982). The influence of some environmental factors and earthworm populations on sweet potato yields have been studied by Rose and Wood (1980).

Other reseach work

"Kaukau rice". Experiments on producing a dried sweet potato product known as "kaukau rice" were done in 1977. Siki (1979) and Thomas (1982) describe the process. No further production was carried out because of an inadequate supply of tubers, low sales due to high cost, poor consumer acceptance and poor marketing (Thomas 1982).

Littleleaf disease. Some work has been done to identify the causal organism of the littleleaf condition and on methods of transmission (Van Velsen 1967). This and other work is reviewed by Pearson (1982).

Stockfeed. Sweet photo tuber and foliage have been evaluated as pig and poultry feed. Malynicz (1971) found that raw sweet potato and a 53% crude protein concentrate gave satisfactory returns for growing pigs. Supplementation of standard rations with sweet potato foliage was not found to improve pig performance (Malynicz and Nad 1973). Rose and White (1980) examined the apparent digestibility of raw sweet potato by village pigs. Live weight gains of pigs foraging in old sweet potato gardens and on fallow land have been compared by Rose (1981). A tethering system of pigs grazing a sweet potato crop has been found to be successful (Rose 1976).

Watt (1973) summarizes the results of other research on feeding sweet potato to pigs. This includes the fact that cooking sweet potato increased live weight gain when compared with raw sweet potato and that pigs grazing sweet potato require a protein supplement of 500 g concentrate per pig per day for optimal growth.

Turner *et al.* (1976) examined various diets based on sweet potato and a protein supplement as poultry feed. They concluded that unless concentrate prices are low and sweet potato is considered a free food, it is more economic to use a fully prepared ration.

Economic research. Little economic research has been published on sweet potato. Von Fleckenstein (1976) examined price data for the Goroka market and concluded that sweet potato growers respond to immediate market conditions and to prices as far as they are able.

Recent, current and future research

A number of researchers have completed work that is not available at the time of writing. This includes work by M. Anders and others in the Southern Highlands on cultivar evaluation, the effects of nematode damage, plant density, time of planting, fertilizers and analyses for trypsin inhibitors; work by S. Goodbody and R. Hide in Chimbu on fertilizers, time of planting and cultivar evaluation; work by G. King at Laloki on fertilizers and cultivars; work by S. Sar and J. Sutherland at Laloki and Bubia on insect pest control; work by R.M. Bourke and E. D'Souza in the Southern and Eastern Highlands on crop seasonality. It is likely that much of this work will be published over the next few years.

Ongoing work includes cultivar evaluation and some breeding at Aiyura, Mendi and Laloki; plant nutrition studies at Laloki and in the Southern Highlands; and entomological studies at Bubia.

Given the importance of sweet potato in Papua New Guinea, and the likely continued expansion of production, it is essential that the research work done so far be built upon by further research so as to benefit the nation's growers. A number of research needs are apparent, as follows:

1. Further breeding of new cultivars and evaluation of existing ones is needed.
2. A considerable amount of research work, especially at Aiyura, has not been collated into report form or published. This includes research on cultivars, fertilizers and growth analysis. Analysis and writing up of this work would be valuable.
3. Data on nematode, insect and disease problems are poor, especially on the economic significance of the various pests. Work is needed in this area.
4. Our knowledge of sweet potato in traditional farming systems is still inadequate. For example, we know little of crop and human responses to environmental stress such as excessive soil moisture and further research in this direction would be valuable.

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